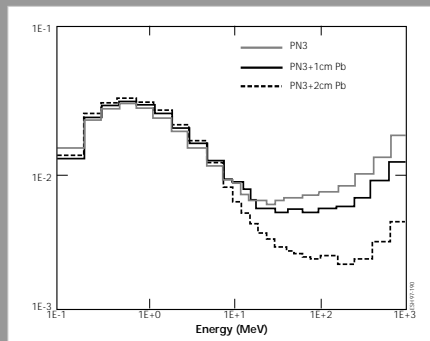
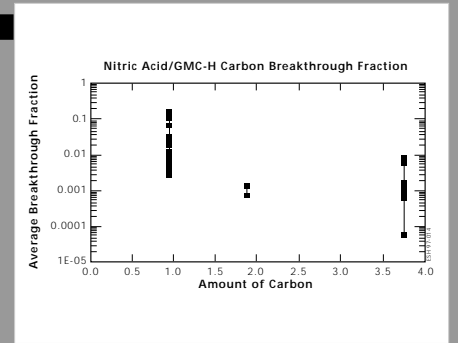
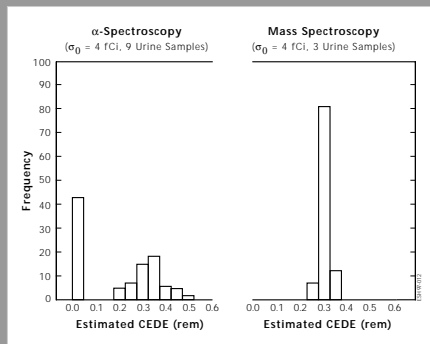


*Technology Development, Evaluation,
and Application (TDEA) FY 1996 Progress Report*
Environment, Safety, and Health (ESH) Division



Los Alamos
NATIONAL LABORATORY

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The previous report in this series, unclassified, is LA-13191-PR.

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*Technology Development, Evaluation,
and Application (TDEA) FY 1996 Progress Report*

Environment, Safety, and Health (ESH) Division

*Prepared by
Larry G. Hoffman*

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Technology Development, Evaluation, and Application (TDEA) FY 1996 Progress Report

Environment, Safety, and Health (ESH) Division

Prepared by Larry G. Hoffman

Abstract

The Technology Development, Evaluation, and Application (TDEA) Committee funded seven projects in FY96—three for the first time and four continued from FY95. As a result of these projects, investigators produced 32 papers that they published in professional journals, proceedings, and Los Alamos reports or presented at professional meetings, including one international meeting. Three of the projects attracted matching funds totaling \$200K.

Results and information generated by six TDEA projects are already leading to improved worker health protection: designing improved safety into a proposed Los Alamos National Laboratory facility, measuring occupational neutron doses (two projects), measuring plutonium in urine, and evaluating the use of respirator cartridges for use in nitric acid environments. Another project accumulates data for the Laboratory's National Environmental Protection Act program, which protects the public and workers from impacts to environment, safety, and health.

Introduction

The public expects that the Los Alamos National Laboratory (LANL, Laboratory) will conduct its operations in a manner that prevents negative impacts to environment, safety, health (ES&H). To achieve this goal within budget, the Department of Energy (DOE) and the Laboratory must develop new technologies and implement innovative approaches that will cost effectively improve ES&H protection.

In FY95, the Environment, Safety, and Health (ESH) Division initiated the TDEA program by allocating \$300K of its annual budget (<1% of its operating budget) to technologies that would more effectively help solve or improve Laboratory problems. Funding for this first year supported six months of work (see LA-13191PR); FY96 was the first full year of the program. In FY96, ESH Division increased the allocation for TDEA-funded projects to \$400K (<1% of its operating budget). The program's specific focus on answering Laboratory needs to solve ES&H problems makes it unique.

The TDEA Committee established the following program priorities:

- Improve ES&H protection to Laboratory workers and the public;
- Support Laboratory mission objectives;
- Respond and build on the unique expertise of the Laboratory and Laboratory requirements;
- Achieve success within three years; and
- Find potential to transfer technologies to other DOE sites.

The TDEA Committee assigned priority status to four ES&H areas: dosimetry, instrumentation, monitoring, and neutron measurement. Each area presents an opportunity to improve ES&H and benefit the Laboratory by solving technically complex problems. In FY95, the committee funded five projects. In FY96, the TDEA program expanded from five to seven projects. The projects were selected and funded from a field of 40 proposals. Three of

these projects represent new proposals; the remainder continue from FY95.

Projects funded for FY96 are

- Applications of Thermal Ionization Mass Spectrometry to the Detection of ^{239}Pu and ^{240}Pu Intakes;
- High-Energy Neutron Dosimetry and Spectroscopy;
- Development and Implementation of the LANL Neutron Extremity Dosimeter;
- Optimization of Continuous Air Monitoring (CAM) Instrument Placement;
- A Polymeric Barrier Monitor to Protect Workers;
- Evaluation of Commercial Air-Purifying Respirator Cartridges for Protection against Vapors of Nitric Acid; and
- Seasonal Movements, Activity Patterns, and Radionuclide Concentrations of Rocky Mountain Elk (*Cervus elaphus nelsoni*) and Mule Deer (*Odocoileus hemionus*).

• **Publication and presentation of funded projects.** TDEA-funded FY96 projects have resulted in 32 publications and presentations. Two presentations were made at an international meeting. (See pages 20-21, "Publications and Presentations.")

• **Cost savings to the Laboratory through efficiencies gained by developing technology.** Although specific cost savings derived from the program cannot be projected into the future, current projects provide some early examples of TDEA-generated cost savings:

- Confirmed that the currently used air-purifying respirator cartridges are adequate in nitric acid vapor environments and eliminate the need for additional worker protection controls such as special ventilation and airline respirators. Work in these environments can be performed without the addition of more expensive types of respiratory protection.
- Provided data concerning the effects of Laboratory operations on deer and elk migrating in the eastern Jemez mountains. The National Environmental Protection Act (NEPA) requires documented scientific

information to demonstrate that no adverse effect to the environment will result from Laboratory activity.

• **New technologies.** TDEA-funded projects are resulting in technologies that yield better protection and reduced cost:

- Results from the Optimization of CAM Placement project are proposed for use in the design of an addition to the Laboratory's Plutonium Facility. Improved CAM placement will introduce cost savings and will mitigate against unnecessary exposure to airborne plutonium and interrupted operations.
- Improved methods of monitoring worker high-energy neutron dose and extremity neutron dose will improve worker protection and reduce worker turnover rates.
- Off-the-shelf technology has been developed to monitor elk and deer movements for use in the National Environmental Protection Act (NEPA) process and reduction of risk to the public from elk.

• **Ability to attract external funding.** Three TDEA-funded projects received a total of \$250K in additional Laboratory funding from sources outside ESH Division. Other organizations also contributed in-kind resources such as accelerator beam time, analytical services, space, materials, and labor.

ESH Division plans in the future to redefine TDEA program priorities using input from the line organizations. Consequently, the program should become more successful in dealing with ES&H problems that impact on the productivity of line organizations. ESH Division hopes to extend the TDEA program to further support Laboratory-wide line organization involvement in developing ES&H technologies.

This report includes summaries of each project. We hope that interested readers will follow up with the publications noted or directly with the principal investigators to obtain additional information.

Applications of Thermal Ionization Mass Spectrometry to the Detection of ^{239}Pu and ^{240}Pu Intakes

Principal Investigators: W. C. Inkret, G. Miller, Policy and Program Analysis (ESH-12); D. W. Efurd, Nuclear and Radiochemistry (CST-11); D. J. Rokop, Environmental System and Waste Characterization (CST-7)

Co-investigators: D.L. Wanningman, Health Physics Operations (ESH-1); D. Lewis, Radiation Protection Services (ESH-12); H. Poths, T. M. Benjamin, D. E. Dry, F. R. Roensch (CST-11)

Funding: FY96, \$57K

Introduction

Current DOE regulations require routine bioassay monitoring for all workers who have a reasonable potential for intakes of radioactive materials in a single year that may result in a committed effective dose equivalent (CEDE)¹ of 1 mSv. The term “monitoring” is defined in the Code of Federal Regulations as “the measurement of quantities ... of radioactive material and the use of the results ... to evaluate potential and actual exposures” (2). In the case of a relatively insoluble form of ^{239}Pu , for example $1\text{ }\mu\text{m}^{239}\text{PuO}_2$, the inhalation of 1 Bq (1 Bq = 1 disintegration per second) in each month of the year will result in 1-mSv CEDE.

Detection of plutonium in urine may be used to assess both occupational and environmental intakes of plutonium (3, 4, 5). The historically accepted method for detecting occupational intakes and assessing the dosimetric consequences of plutonium inhalation is by radiochemical evaluation of urine samples collected from the individual (3, 5, 6, 7, 8, 9, 10, 11). The urine radiobioassay technique used for the basis of plutonium intake estimates at LANL has a classical minimum detectable activity (MDA)² on the order of 20 fCi day⁻¹ (150 mBq) (13, 4, 14, 11). These radioanalytical detection capabilities result in a missed CEDE of 2- to 10-rem in the year of intake, for routine biannual sampling (11).

In most cases, inhalation intakes of ^{239}Pu , from environmental sources, occupational exposures occurring decades earlier, and low-level occupa-

tional exposures are not detectable using current radiochemical techniques (4). It is obvious that current radiochemical techniques do not meet the requirements described in 10CFR Part 835. In addressing this technical shortfall, DOE has recommended the use of “the best practical state-of-the-art bioassay monitoring methods.”³

The LANL Nuclear and Radiochemistry Group and Environmental Systems and Waste Characterization Group have an established ultrasensitive actinide analysis program. This program uses class-100 clean room technology, ultratrace actinide chemistry, and thermal ionization mass spectrometry (TIMS) for detecting low-levels of ^{239}Pu , ^{240}Pu , and other actinides in biological and environmental matrices (15, 16, 17, 18).

The sensitivity of TIMS for detecting these plutonium isotopes in biological samples has been reported on the order of 1 μBq ($\approx 10^6$ atoms of ^{239}Pu) (17). The fission track method (FTM) for urine bioassay developed at the University of Utah and Brookhaven National Laboratory has a reported MDA of approximately 2.6 μBq 24h⁻¹ for ^{239}Pu (4, 19).

Detection of ^{239}Pu by *in vivo* lung counting is limited by detection capabilities. The Laboratory’s MDA for *in vivo* chest counting is on the order of 2000 Bq for ^{239}Pu (11, 20). This measurement

capability corresponds to detecting an intake of 15 kBq and a resulting minimum detectable CEDE of greater than 1 Sv⁴. Detection by analysis of fecal samples has shown some promise; however, the associated biological variability and contributions from ingested plutonium produce data with unacceptable statistical errors (11).

¹ The concepts of committed dose equivalent and CEDE are discussed in NCRP Report No. 84 (1). The NCRP considers these quantities to be useful for radiation protection planning and for demonstration of compliance and recommends their use for such purposes. The concept of committed dose involves the extrapolation of cumulative dose to 50 years into the future.

² Classical MDA refers to the definition given by Curie regarding detection limit (L_D) (12).

³ US DOE, Office of Worker Protection Programs and Hazards Management, Radiological Control Technical Position, RCTP 9505, Technology Shortfalls and Dose Determinations for Radioactive Material Intakes.

⁴ If the measurement is made at 180 days after an acute inhalation intake of 1 μm activity-median aerodynamic diameter, inhalation class Y, ^{239}Pu .

Method

Urine *excreta* were collected for a 24-hour interval, from a population of individuals who work at LANL. Each 24-hour urine sample was traced with ultrapure ²⁴²Pu. The plutonium fraction was coprecipitated with alkaline earth phosphate at room temperature. The precipitate was dissolved in 8-M HNO₃, heated, and adsorbed onto anion exchange resin. The plutonium was eluted from the exchange column with successive rinses of 0.5-M HCl, HI-HCl reagent and H₂O. The elute was then evaporated to dryness. The plutonium was dissolved in 12-M HCl containing a drop of H₂O₂ and adsorbed onto a second anion exchange column. The column was rinsed with the HI-HCl reagent. The plutonium was then electroplated onto a platinum disk. The platinum disk was analyzed, under vacuum, with a 300-mm² solid state surface barrier detector for 10,000 minutes. The plutonium was removed from the platinum disk with HF and HNO₃. The sample was evaporated to dryness. The plutonium was dissolved in 12-M HCl containing a drop of H₂O₂ and adsorbed onto a third anion exchange column. The sample was rinsed with 8-M HNO₃ and the plutonium was eluted with a rinse of HBr. The sample was deposited on a platinum wire filament and analyzed for ²³⁹Pu and ²⁴⁰Pu atom contents by thermal ionization mass spectrometry. All chemical processing was performed in class-100 clean rooms.

Results

Reduced measurement uncertainty. The current radiochemical α -spectroscopy technique used at LANL for plutonium urine bioassay has a measurement uncertainty of 150 μ Bq per 24-hour urine sample (14). This measurement capability corresponds to detecting an intake of (1 kBq), and a resulting minimum detectable CEDE of 90mSv⁷. Application of the class-100 clean room radiochemistry and thermal ionization mass spectrometry to the determination

of plutonium concentration in the collected urine samples yielded an average measurement uncertainty of 0.13 fCi per 24-hour urine sample. This measurement capability corresponds to detecting an intake of 40 Bq and a resulting minimum detectable CEDE of 3mSv⁷. The results listed in table 1 summarize the detection capabilities based on this study and the associated parameters from other techniques.

Ratio of ²⁴⁰Pu to ²³⁹Pu. An interesting feature of the mass spectrometry technique is the capability to obtain information regarding the presence and concentration of both ²³⁹Pu and ²⁴⁰Pu (15, 17). The ratio of ²⁴⁰Pu atom to ²³⁹Pu atom content in a sample reveals some information about the source of the plutonium (17). For example, material used in the fabrication of the World War II nuclear weapons had a ratio of 0.01, weapons material in current use has a ratio 0.06, and environmental material from open air testing has a ratio of 0.18. This information is applicable in establishing the approximate era and source of intake. Preliminary results indicate that this technique will identify statistically significant ratios when ²³⁹Pu urine concentrations exceed 400 μ Bq per 24-hour urine sample ($\approx 5 \times 10^8$ atoms).

Discussion

Distributions of estimated values of CEDE were generated by two 100-trial Monte Carlo experiments. The assumed intake scenario was an acute inhalation of 37 Bq, 1- μ m AMAD, inhalation class Y, ²³⁹Pu. It was further assumed in our analysis that urine samples were collected, beginning at one day after the inhalation. Two urine sampling protocols were used. The first protocol requires collection of nine 24-hour urine samples over an eight-month period (on days 1, 3, 5, 8, 15, 30, 60, 120, and 240). The second protocol uses three 24-hour urine samples collected on days 1, 3, and 5 after the intake.

The samples from the first protocol were assumed to be analyzed by current α -spectroscopy-radiochemical techniques. A measurement uncertainty (σ_0) of 4 fCi per 24-hour urine sample and a biological variation of 30% were used in conjunction with the ICRP, Publication 30, lung model and the Jones plutonium excretion model in the Monte Carlo calculation to generate 100 random realizations of plutonium concentrations in urine due to the defined intake intake (8, 9, 21).

Table 1. Summary of various bioassay techniques including the average measurement error, the associated classical MDA, and the minimum detectable dose at 180 days after an acute intake of inhalation class Y, 1 μ m AMAD ²³⁹Pu, based on a single urine sample.

Method	σ_0 μ Bq 24h ⁻¹ [atoms 24h ⁻¹]	MDA μ Bq 24h ⁻¹	CEDE mSv
LANL α -spec	150 [2x10 ⁸]	20 700	90
LANL TIMS	4.8 [5x10 ⁶]	22	2.6

The samples from the second protocol were assumed to be analyzed by clean room radiochemistry and thermal ionization mass spectrometry. The measurement error (σ_0) was reduced by an order of magnitude to 0.4 fCi per 24-hour urine sample. A biological variation of 10% was applied in conjunction with the ICRP, Publication 30, lung model and the Jones plutonium excretion model in the Monte Carlo calculation to generate 100 random realizations of plutonium concentrations in urine due to the defined intake (8, 9, 21).

The two sets of random realizations were analyzed with a mathematical technique developed at Los Alamos by Miller et al. (14, 22, 23, 24, 25). The results of the two analyses are displayed in figure 1. A summary of the input parameters for the Monte Carlo exercise and the resulting distributional parameter estimates are contained in table 2.

Conclusions

The results presented here reveal the significance of lowering measurement errors. The thermal ionization mass spectrometry results are superior; they show little bias and have a smaller standard error of the estimated CEDE.

The improved sensitivity will provide dose estimates from plutonium intakes at lower levels than previously achievable. Cases may exist where individuals may have had intakes that had not been detected with the α -spectroscopy method. Although, these individuals will be assigned annual doses from previous intakes, assignment of a CEDE, the year of intake, and the amount of intake may not be possible. A method with greater sensitivity identifying intakes at lower levels should also increase the number of detected intakes. This increase in identified intakes should not be confused with an increase in the number of exposures or interpreted as an increase in collective dose over previous time periods. Incorrect interpretation of improved monitoring capabilities could provide negative feedback, ultimately discouraging improvements and ignoring the true risk to worker populations.

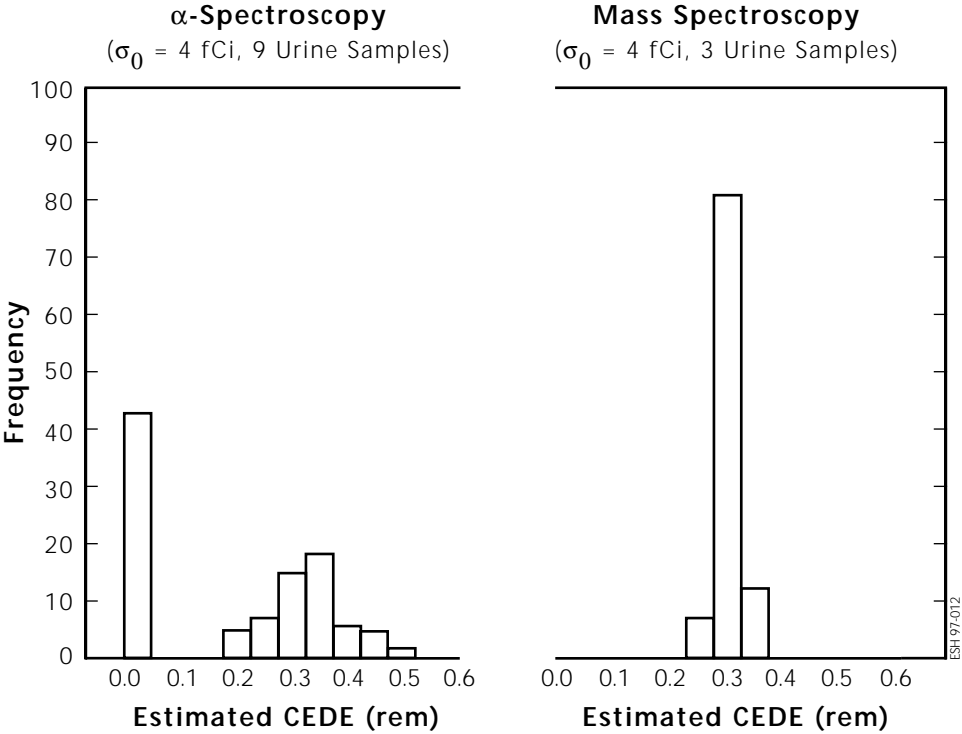


Figure 1. Distribution from two 100-trial Monte Carlo experiments. Both distributions are based on an inhalation of 1 nCi, inhalation class Y 1 μ m AMAD, ²³⁹Pu. This intake corresponds to a CEDE of 300 mrem. The biological variability used for alpha spectroscopy analysis of a simulated 24-hour urine sample was 30%. The biological variability used for TIMS analysis of a true 24-hour urine sample was 10%.

Table 2. Results from Monte Carlo exercise-generated urine data to test the effect of a lower measurement error on final estimates of CEDE

Measurement	σ_0 Bq	$\sigma_{\text{Biological}}$	False-Negative Fraction	σ_{CEDE} mSv	Bias mSv
TIMS (3 samples)	15	0.1	≈ 0	≈ 0.5	≈ 0
α -spec (9 samples)	150	0.3	≈ 0.4	≈ 1	≈ 1

Comparison of collective doses and number of identified intakes should take into account the improved sensitivity of the monitoring technique.

The availability of a high-quality estimate of CEDE in combination with a shorter turn around time and fewer samples results in better work place decision making and compliance with DOE regulations.

Deliverables

- A method for detecting low concentrations of ²³⁹Pu in urine—complete.
- Statistical distribution information for application of Bayesian techniques—complete.
- Participation in DOE Laboratory Accreditation Certification process—currently participating.

- Contacts with DOE, the Defense Nuclear Agency, and other potential funding agencies— participating in DOE OIHS intercomparison for contract to monitor Marshall Islands and collaborating with National Oceanographic and Atmospheric on North Slope Risk Assessment.

- Publication of results— results presented at 1996 Annual Meeting of Health Physics Society and at 1996 Annual Meeting on Bioassay, and Environmental Radiochemistry. Manuscripts in preparation for publication in open literature.

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High-Energy Neutron Dosimetry and Spectroscopy

Principal Investigators: R. T. Devine, H.-H. Hsu, Health Physics Measurements (ESH-4) and L. S. Walker, Health Physics Operations (ESH-1)

Funding: FY95, \$14K; FY96, \$14K

Introduction

In this project, we calibrate and use neutron detection devices—dosimeters, monitors, fission chambers—at high-neutron energies ($20 \text{ MeV} < E_n < 800 \text{ MeV}$) for application at the Los Alamos Neutron Scattering Center (LANSCE). The work extends current methods to higher energy determination and real-time monitoring of fields outside of shielding and establishes standard calibration fields.

The objective of this project is to remedy problems in current methods used at LANSCE for determining energy fields expected outside of shielding. To detect neutrons using dosimetry, LANSCE researchers have been using photographic emulsions: Kokak monitoring film, personal neutron type A (NTA); and the Health Physics Instruments Model 2080 Pulse Neutron Survey Meter, referred to as the Albatross. The problems encountered in using NTA film are a large variation in energy response; the fading of tracks registering on the film, which requires a short issue period; and labor-intensive procedures for film development and track counting. The problem with the Albatross is that it has not been calibrated at the higher energies (20–800 MeV) expected at the facility.

High-energy neutron dosimetry uses the following means: thermoluminescent dosimeters (TLDs), NTA Film, *Makrofol* plastic track etch detectors (with and without fission foils), and chemically etched (CE) CR-39 or electrochemically etched (ECE) CR-39. (CR-39 is the commercial name for the plastic polyallyl-diglycol carbonate that is used as lens material in spectacles.) Each of these means has different limitations: TLDs are insensitive to higher neutron

energies; and *Makrofol* and CR-39 ECE dosimeters must be developed in small batches because they require a electrochemical cell to produce the high fields required for development. CE allows larger batches to be processed at one time and CE foils can be read automatically by using the PN3 system, which combines the foils supplied by BICRON♦NE and the AUTOSCAN 60. The introduction of the PN3 system required us to determine the energy response of the dosimeter by using fields at the LANSCE Weapons Nuclear Research (WNR) facility.

To determine the Albatross response, we used fields at the WNR facility. The Albatross uses the principle of nuclear activation to detect neutrons. In this process, a 25-cm-diameter polyethylene moderator thermalizes neutrons, which are captured by a silver foil surrounding a Geiger Muller (GM) tube. The count of the resulting beta activity is proportional to the acquired neutron dose. We used a second GM tube surrounded by tin foil to subtract background.

The Bonner sphere system used to determine neutron spectra comprises a set of hydrogenous spheres (usually polyethylene) with diameters from 2–18 inches surrounding a detector. TLD material and ^3He detectors are placed in the center of the sphere to measure the thermalized neutrons that are slowed down by the spheres. The response of the detectors in spheres of differing thickness are entered into a program with a best estimate of the spectrum to determine the actual spectrum. A problem in using Bonner spheres for the spectroscopy of neutrons with energy $>20 \text{ MeV}$ is that the response functions for differing polyethylene thickness become similar in shape. This similarity makes the spectral unfolding quite difficult. The possibility that the use

of a neutron detector, such as CR-39, which is sensitive to high-energy neutrons, combined with lead radiator that has a significant variation of cross section due to the $\text{Pb}(n,xn)$ reaction above 20 MeV, led to the theoretical investigation of the response of a CR-39 detector with lead in front of it.

Bismuth fission chambers have been used to determine neutron fluxes above 50 MeV. LANSCE has one of these devices and studies of the current response using time-of-flight methods and better electronics were installed to determine modifications that would improve performance. This allows better determination of neutron fluxes for calibration.

Progress and Results:

Dosimetry. ESH-4 and ESH-1 introduced the chemical etch dosimeter as the dosimeter of record for LANSCE, thereby saving the investigators both processing time and cost. The details of the savings are shown in table 1. We determined the response of the dosimeter in two runs, using the WNR facility's white neutron spectra scattered off a tungsten target.

The first run used the 60° right (60R), 20-m flight path with 1, 2, 4, and 8 in of polyethylene for hardening the spectrum. Corresponding spectrum average energies ranged from 20 to 100 MeV with a broad energy distribution. The second run used the 15° port and 1, 2, 4, 8, and 16 in of polyethylene. Here the average energies ranged from 30 MeV to 300 MeV, again with rather broad energy distributions. The breadth of the energy distributions is not an essential problem because for health physics purposes, this type of spectrum is met in practice.

We also performed one run using the Blue Room lithium target, which corresponds to about a 600-MeV average energy. The net result of the measurement is that the dose assigned on the basis of a bare californium calibration must be multiplied by a factor of two to two-and-a-half. The *Bundesamt für Strahlenschutz* in Berlin had conducted an intercomparison; we show the results with the use of two as the conversion in figure 1.

We developed a model for a new type of detector for high-energy neutrons, using CR-39 as a detector and lead as a moderator. We then calculated the response of CR-39 in terms of charged particles produced per-unit-incident neutron for a foil of 2-cm diameter and 0.15-cm thick. Another set of calculations was performed using cylindrical slugs of 2-cm-diameter and 1-cm- and 2-cm-thick lead with the foil positioned on the end of the slug so that the neutron beam had pass through the lead. While this is not equivalent to a Bonner sphere arrangement, it is close enough to make some test of the hypothetical response. Figure 2 shows the results for protons, the particle expected to produce tracks in CR-39. Track etch detectors used as dosimeters to detect alpha particles and proton recoils from neutrons. There is sufficient evidence from the data presented above to justify experimentation using these detectors at high energies. Exposure to a neutron spectrum with peak at 100 MeV should yield a significant difference among the three thickness of lead. The major difficulty in applying track etch detectors at high energies will be the determination of the energy response and the large angular dependence.

Albatross. Figure 3 shows Albatross response functions. We estimated dose rate from the 15-L spectra calculated from Monte Carlo Neutron Particle (MCNP) and Los Alamos High-Energy Transport (LAHET) Monte Carlo calculations. The error in calibration can be from three to five. A Cooperative Research and Development Agreement with the manufacturer would be the best way to correct the response function at higher energies.

Table 1. Track Etch Dosimeter Characteristics

	NTA	Electrochemical etch	Chemical etch
Counting Area (cm ²)	0.01	0.6	1.6
Batch Size	20	24	240
Overhead/batch (foils) (Control and Background)	2	4	8
Throughput (batch/day)	3	3	4
Preparation (hour/batch)	3	1	2
Processing (hour/batch)	2	6	8
Reading	Manual	Automatic (Prototype)	Automatic
Readout Time (hour/batch)	1	1	1
Material (\$/foil)	0.50	1.30	2.00
Labor (min/foil)	12	5	2
Issue Period (month)	1	3	3

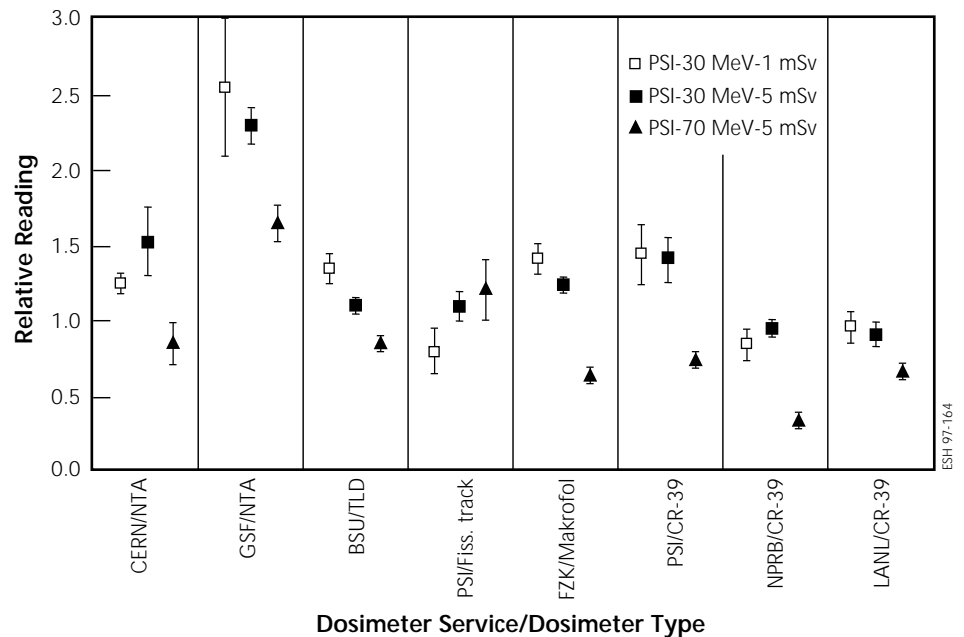


Figure 1. Comparison of neutron individual dosimeters in high-energy reference fields at PSI/Villigen (average of 4 dosimeters +/-SD)

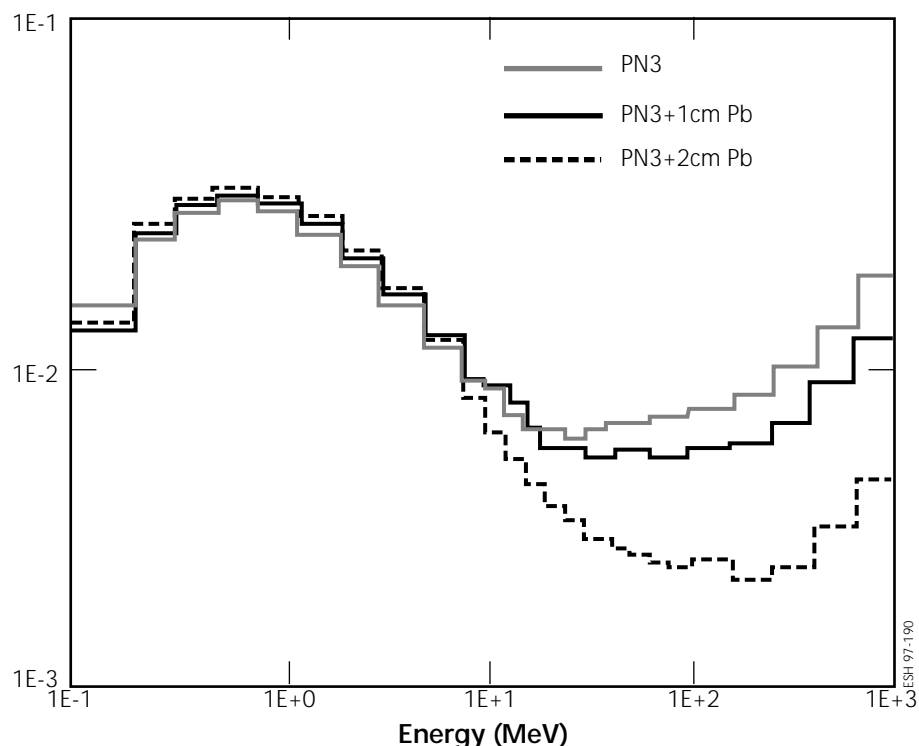


Figure 2. Response of PN3 to neutrons

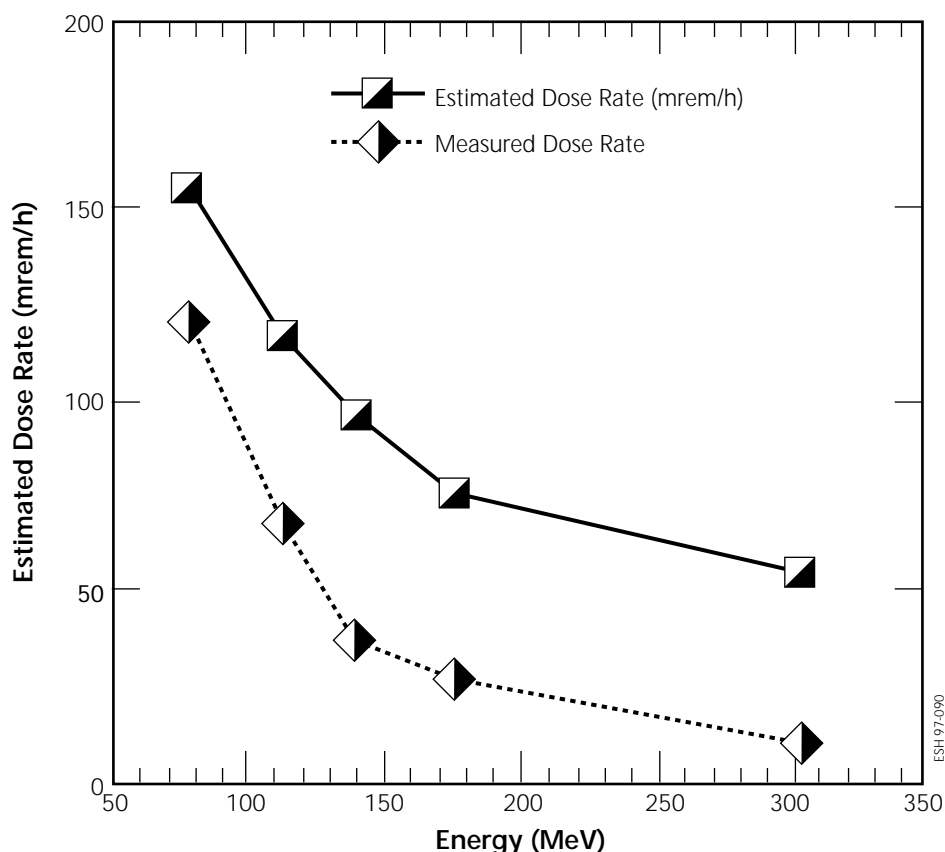


Figure 3. Health physics instrument (HPI) 2080 neutron dose response as a function of energy (MeV)

Bonner Spheres. The detectors for the LANSCE Bonner sphere set were three TLD-600 and three TLD-700 chips. We used the following detector configurations: bare, cadmium-covered, and 2-, 3-, 5-, 8-, 10-, 12-, and 18-in polyethylene spheres. We unfolded the spectra using the codes: BN2, NS2, BUNKI/BON31G, and BUNKI/SPUNIT. Each code used the Sunna response function. In figure 4, we present the averaged results of the unfolding codes. For comparison, we show the computed spectra in figure 5. At energies <50 MeV, the existing codes fit the spectra; for energies >50 MeV, the codes do not adequately predict flux. An improvement would be use of the system applied by the *Deutsches Elektronen-Synchrotron* Facility (DESY), which uses the same detectors and spheres but adjoins nuclear track detectors. These additional detectors with the DESY response functions and the unfolding code LOUHI, appears to yield better results. In our case, the addition of the bismuth fission chamber should also improve the response at higher energies.

Bismuth Fission Chamber. We modified the bismuth fission chamber to use P-10 counting gas to replace the carbon dioxide/argon mixture. By selecting a preamplifier better matched to the capacitance of the chamber, we have obtained a better time response. The chamber window was replaced with a thinner window so we could measure fission events rather than the charged particle avalanche associated with fission events. These modifications have allowed us to compare the response of the bismuth fission chamber and a uranium fission chamber for pulse height and time-of-flight spectra with collimated neutron beams. For isotropic exposure, we will construct a new carbon composition housing to replace the old, thick aluminum housing that produced charged particle avalanches.

Deliverables

- Proposal to DOE for establishing standard fields for high-energy neutron dosimetry and intercomparison studies.

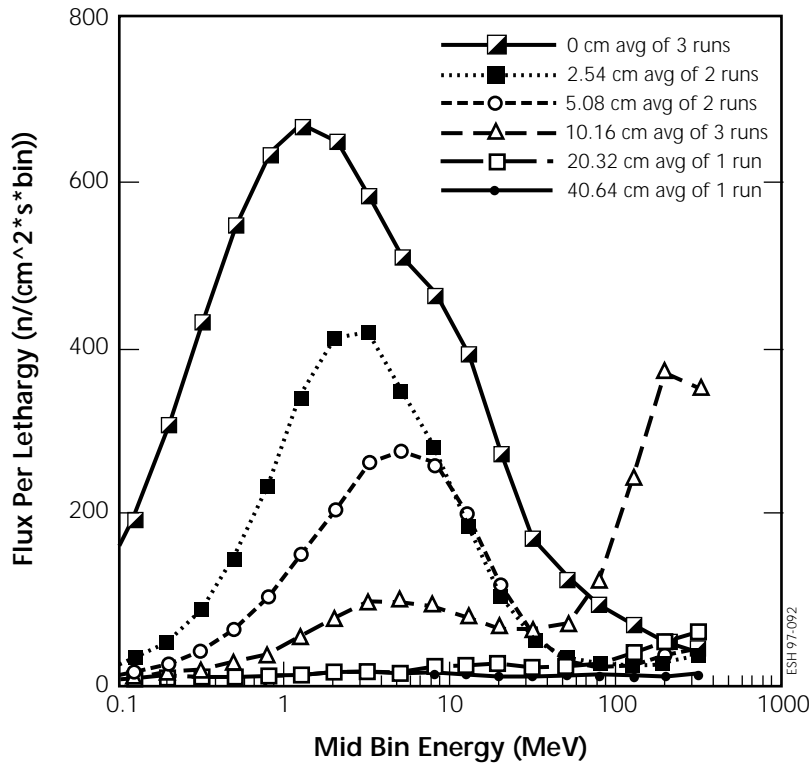


Figure 4. Unfolded neutron flux averages ($n/cm^2 \cdot s \cdot bin$) per energy bin (MeV) as a function of poly filtration (cm) (WNR15L flight path)

- Measurements of fields outside of shielding, using a bismuth fission chamber.
- Exposures of dosimeters at the WNR Facility to high doses and dose rates to study the effects on the current dosimetry system.
- Complete studies on energy dependence of the response of Bonner spheres to high-energy neutrons.
- Exposure of Bonner spheres made from materials with (n,xn) reactions and using chemical etch dosimeters to achieve increased response and energy resolution.
- Experimental confirmation of the redesigned bismuth fission chamber response.

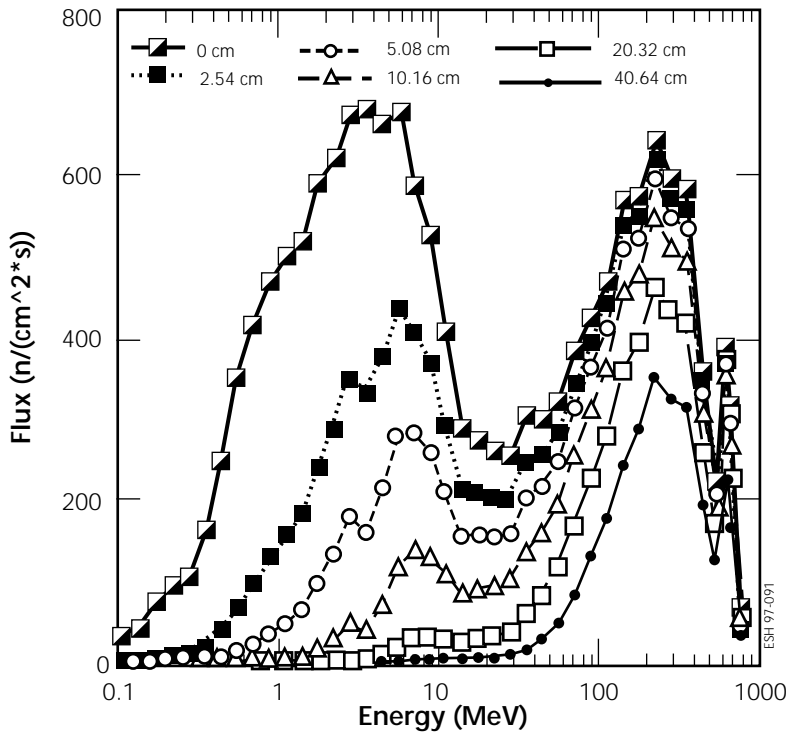


Figure 5. LAHET calculated neutron flux density vs. energy (MeV) as function of poly-filtration (cm) (WNR15L flight path)

Development and Implementation of the LANL Neutron Extremity Dosimeter

Principal Investigators: M. W. Mallett, J. M. Hoffman, Health Physics Measurements (ESH-4)

Funding: FY96, \$19K

Introduction

Presently, no measurement of neutron dose to extremities is made at LANL. Rather, as a policy, dose is assigned as being equal to the measured extremity gamma dose. The policy was instituted at this Laboratory because historically, we have lacked adequate means to measure neutron extremity dose. One reason for this situation is that insufficient tissue mass is present in the extremities to thermalize incident-fast neutrons to be measured by thermoluminescent dosimeter (TLD) materials. Periodic measurements of glove-box operations at the Laboratory indicate that the presumed 1:1 neutron-to-gamma dose policy is not uniformly applicable to accurately assess neutron doses to extremities.

Recent developments in high-energy neutron dosimetry made by the Measurements Technology Support and Personnel Dosimetry Operations teams of ESH-4 suggest a new dosimeter could be constructed to effectively measure neutron extremity dose. The proposed dosimeter design features a single PN3¹ film, a CR-39 detector that exhibits a relatively flat energy response over the energy range 0.2–20 MeV. The dosimeter also includes two ⁶LiF and two ⁷LiF TLD phosphors. One of each type is shielded by a 0.16-mm-thick cadmium filter. The dosimeters are packaged in a comfortable, easily donned canvas gortex wrist strip. This unique combination of detectors provides a satisfactory dose measurement for neutron energy spectra present in glove-box environments at the Laboratory.

Progress and Results

We used common sewing materials to construct a prototype dosimeter holder. Initial laboratory calibration measurements indicated dosimeter components could be used to effectively resolve neutron dose to extremities for a variety of neutron spectra. Several TA-55 glove-box workers reviewed the prototype dosimeter holder. We solicited suggestions from them concerning comfort and donning and doffing ease, then significantly redesigned the dosimeter based upon their recommendations. A local seamstress manufactured the final design.² Pilot testing of the new dosimeter continues at TA-55, where the dosimeters have been selectively issued to personnel.

Laboratory calibration of the dosimeter was conducted in a glove-box mockup simulating typical shielding conditions in use at the Laboratory. To account for radiation scattering in extremity tissue, we used a radiographically equivalent arm/shoulder phantom³ for these calibrations. By increasing moderation of a ²⁵²Cf source, we generated different neutron energy spectra. These data provided the basis for characterization of the dosimeter response, including PN3 detector under-response and TLD-600/-700 ratios.

Deliverables

The deliverable for this project is the development, deployment, and accreditation of the Laboratory's neutron extremity dosimeter. During FY97, the dosimeter will become an integral part of the LANL external dosimetry program administered by ESH-4.



Components of the LANL neutron extremity dosimeter



Experimental calibration of the prototype dosimeter holder

¹ Bicron-NE, 6801 Cochran Road, Solon, OH 44139

² Creative Sewing Services, 412 Georgene, Albuquerque, NM

³ Radiology Support Devices, 1904 E. Dominguez Street, Long Beach, CA 90810

Future Plans

During FY97, we will continue in the laboratory and field to characterize the finalized dosimeter design. Field testing will include irradiation in the high-energy neutron fields found at the Los Alamos Neutron Scattering Center. Additional issues to be resolved during FY97 pertain to continued worker evaluation of the dosimeter. For example, in response to worker comments, a more durable barcode labeling system will be implemented that includes information denoting the proper orientation of the dosimeter on the body.

Preparation of the dosimeter for pending DOE Laboratory Accreditation Program testing is an essential component of this project. During FY97, we will conduct characterization studies, such as dosimeter response in mixed fields and angular dependence. We will continue to pursue publication of this dosimeter project in peer-reviewed journals and throughout the Laboratory to potential users.

Optimization of Continuous Air Monitoring (CAM) Instrument Placement

Principal Investigators: J. C. Rodgers, J. J. Whicker, Y. Yang, M. E. Moore, Health Physics Measurements (ESH-4); J. Spore, Nuclear Systems Design and Analysis (TSA-10); R. Scripsick, Industrial Hygiene (ESH-5)

Funding: FY95, \$100K; FY96, \$98K. Additional support for the project (\$110K) was obtained from the Capabilities, Maintenance, and Improvement Project during FY96.

Introduction

In 1992, DOE appraisers found that alpha CAM instruments deployed in certain LANL workrooms probably left undetected (>33% of the time) large releases of plutonium (as large as 500 DAC-hr). Undetected internal radiation exposure to laboratory workers is the probable result of failure to alarm during such releases.¹

DOE 10CFR835 and its implementation guide require that technical basis documents account for rapid, reliable detection of radiation and document the optimum number and placement of CAMs. To date, no demonstrated effective method has carried out the mandates of the implementation guide for CAM use in LANL laboratories.

The overall objective of this project is to develop, test, and demonstrate a method for identifying the optimum number and placement of CAMs in a workroom. The method is based on the computational fluid dynamics (CFD) models of aerosol dispersal in the room and geographical information system (GIS) mapping and decision-making strategies for placement of CAMs. Data input required for workroom environment models includes ventilation pattern and rate, geometry of the room furnishings, and aerosol release characteristics. Determining the optimum number and placement of CAMs will result in the most rapid and reliable CAM alarm, the fewest CAM resources, and consequently, the lowest possible installation and maintenance costs.

Progress

Field studies. We evaluated and analyzed aerosol release data taken in two TA-55 laboratories and sent a report of results and recommendations to Facilities Management (NMT-8) and Health Physics Operations (ESH-1) (Whicker et al. 1996a). The Journal of Health Physics will publish a technical paper on this study (Whicker et al. 1996a). We reported the results of an analysis of particle size effects on aerosol dispersion in a TA-55 workroom and the results of preliminary spatial mapping and decision-making applications to the 1996 Health Physics Society Annual Meeting (Whicker et al. 1996b; Rodgers et al. 1996).

We used comparisons of predicted and observed particle concentrations as a function of time and release location in room 420 of PF-4 to expand and validate a computational fluid dynamics model (GASFLOW) for application to the problem of predicting three-dimensional aerosol dispersion. Predictions were in general agreement with experimental data, particularly during early stages of the release. We presented these findings at the 1996 summer meeting of American Society of Mechanical Engineer's Fluids Engineering Division (Whicker et al. 1996c).

Experimental test room. In the Ultra-High-Temperature Reactor Experiment (UHTREX) building, we constructed and placed instruments in a dedicated experimental test room where we can simulate mock-ups of plutonium laboratory ventilation arrangements and glove-box layouts. As shown in figure 1, an arrangement of multiple ventilation inlets can be provided through the roof. Laser particle counters (LPCs) shown in figure 2 simulate CAM function by measuring test particle concentrations as a function of time. Large arrays (up to 26 LPCs) can be placed around the room to simultaneously record particle concentrations in short time intervals (as little as 10 sec) throughout a puff release episode. A test aerosol (dioctyl sebacate droplet) generator (figure 2) releases a short-duration puff of polydisperse aerosol, simulating a plutonium release. Data from the LPCs are routed through two multiplexers to a personal computer (figure 3) where a large data base is assembled. Thermal anemometry equipment (figure 4) explores the turbulent structure of higher velocity flows in the room.

¹ T. R. Crites, "Alpha Air monitor Alarm Sensitivity: Operational Experience," *Radiation Protection Dosimetry*, 53(1-4), 65-68 (1994).

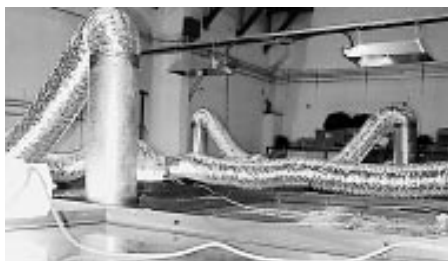


Figure 1. High-energy-particulate-air-filtered air ventilation supply in flex ducting on the roof of the experimental room in the UHTREX facility. Straight sections contain flow conditioning to maintain uniform, nondirectional discharge into the room.



Figure 2. LPC array suspended by cables to specified heights in the experimental room. A mock glove box is shown to the right of the LPC array. The aerosol generator output diffusion tube is seen projecting into the center of the array.



Figure 3. The two multiplexers used to collect LPC particle concentration data from up to 26 LPCs in the experimental room are shown on the table with the host personal computer resting on top. Data collection is automatically binned into two particle size ranges: less than 0.5 micrometers, and greater than 5.0 micrometers. Next to the multiplexers are the control and readout boxes for the IFA-100 /200 2-D thermal anemometer.



Figure 4. The sampling flow through the LPC particle counter array is established by the set of pumps shown beside the table outside the experimental room. The oleic acid pressurization and feed system is shown on top of the table. A portion of the flex tube return air ducting is seen at the left of the picture.

Computational modeling. To be most effective and useful and provide predicted CAM placement during design phases of construction, the CAM optimization process should not have to rely on in-place aerosol testing. We developed a computational approach using CFD dispersion modeling and GIS decision making. Work with GASFLOW shows that 3-D simulations of laboratory environments are computationally intensive. Efforts are underway to investigate alternative numerical solution algorithms to speed convergence.

We have identified and will test a promising alternative and evaluate a parallel-processing approach. Work on the GIS mapping and decision-making approach continues to focus on the problem of properly representing spatial distribution of sampling and modeling errors. This work also focuses on how best to translate CFD model predictions into CAM placement strategies that minimize response time and enhance the probability for a quick, reliable alarm.

Major findings and accomplishments. Our study demonstrates that when CAMs are placed away from corner exhaust register locations, the result is faster, more sensitive detection and CAM alarm. We have analyzed the effect of worker movements in the laboratory following a release. Preliminary results show these movements to have little effect on CAM response. Using a range of particle size aerosols, we found evidence of greater mixing and smaller deposition losses for small particles, which has implications for CAM placement.

We have made significant progress on CFD modeling and GIS mapping. Mapping of concentration patterns over time suggests that aerosol clouds are remarkably structured and remain somewhat cohesive during the initial phases of cloud release and circulation through the room. This finding is of considerable importance because it shows that there is a potential for large worker dose savings to those remote from the release—if early detection can be achieved.

Deliverables

During FY97, we will develop CAM optimization strategies, experimentally test them, and then apply them to the plutonium laboratory upgrade planning process that is underway. These strategies will provide an opportunity to refine and demonstrate optimization methods. It is too early to be able to estimate the course of this important application of methods. We expect a final tested version of GASFLOW by the end of FY97. Modified modules of the IDRISI code GIS have already been constructed for application to CAM optimization, and others will likely emerge as we further explore applications. At the end of FY97, we will document optimization methods in a manual.

A Polymeric Barrier Monitor to Protect Workers

Principal Investigators: R. Hermes, Materials Technology/Coatings and Polymers (MST-7); T. Stampfer, visiting scientist, Industrial Hygiene (ESH-5); J. Macdonald, H. Nekimken, Actinide Process Chemistry (NMT-2)

Funding: FY96, \$58K; \$80K from the Nuclear Materials Technology Division

Introduction

In FY96, we continued the FY95 project to demonstrate the feasibility of making a pentalayered prototype glove finger using commercially available insulator- and conducting-type polymers. The overall objective of the FY96 project was to develop a new type of glove with proper electrical connections that can sound an alarm when the glove is breached by a puncture from sharp metal, glass, or wood splinters.

The goal of the FY96 project was to establish a development contract with North Hand Protection, Charleston, SC, for the manufacture of several prototypes of forearm-length gloves for testing by both MST-7 and NMT-2 personnel.

Progress and Results

After four months of negotiating with the Nuclear Materials Technology Division and the Nuclear Materials Stockpile Management Program Office, we obtained financial support from them (as noted above) for the purchase of specialized video, robotic, and electronic-testing equipment necessary for the project.

The principal investigators at NMT-2 also provided necessary funds to pay for the contract with North Hand Protection. A statement of work for the contract with North Hand Protection was drafted in

March and initially included the incorporation of erbium and bismuth oxides as replacements for the lead oxide in the lead-lined layer of the glove (the lead oxide is considered a hazardous waste). However, after researching the cost and availability of 350 kg of both metal oxides, we abandoned that portion of the work. This contract covered several iterations of glove preparation by North and testing by our Laboratory. At the end of the contract, North was to deliver a final set of 20 pairs of full-length glove-box gloves.

For the first set of pentalayered gloves, poly(chlorosulfonated ethylene) and carbon-filled poly(butylene) were chosen for the electrically insulating and conducting layers, respectively. We received the experimental gloves on September 18 and tested them soon after. All three experimental versions (four of each type for a total of twelve) were found to have unacceptable conductivity for our tests and could not be evaluated for real-time puncture detection. Subsequently, North and Laboratory personnel identified the problem and are adjusting composition of replacement gloves for testing.

Deliverables

- Leveraged funding from the Nuclear Materials Technology Division—commitment made February 1996.
- Glove prototypes by end of FY96—delivered September 1996; not suitable for testing.

Evaluation of Commercial Air-Purifying Respirator Cartridges for Protection against Vapors of Nitric Acid

Principal Investigators: G. Wood, R. Kissane, Industrial Hygiene (ESH-5)

Funding: FY96, \$86K; \$10K was received from the Department of Defense (US Army) for similar, less extensive studies with military canisters.

Introduction

Nitric acid is widely used at LANL; however, the effectiveness of air-purifying respirator acid gas cartridges in protecting workers from vapors of nitric acid is not well established. The National Institute for Occupational Safety and Health and Mine Safety and Health Administration certify cartridges for some acid gases, but not nitric acid. Consequently, ventilation, engineering controls, and air-line respirators (with air-purifying cartridges for escape only) are relied upon for routine operations involving nitric acid. However, for spills or leaks outside of hoods or normal work areas, the only currently documented protection is for use of a self-contained breathing apparatus.

The objective of this work has been to determine whether and under what conditions the cartridges available at the Laboratory are effective in removing vapors of nitric acid so that they can be confidently used with air-purifying respirators.

Progress and Results

We selected two air-purifying respirator cartridges in use at LANL for this study: Mine Safety Appliances (MSA) Company Combination Cartridge GMC-H and MSA Combination Cartridge GME-H. We packed samples of the carbons from these cartridges into a fluorocarbon tube of inner diameter 2.1 cm and passed total air flows of 2-3 L/min through the bed. Carbon sample weights were scaled to correspond at a total testing flow of 2 L/min to the same residence time as one full cartridge at 25 L/min and an average total

breathing rate of 50 L/min (two cartridges). Smaller (1/4, 1/2, 3/4) beds were also tested.

The nitric acid vapors were generated by passing a purge air flow (10-60 mL/min) through a chamber in which concentrated nitric acid was being stirred. The nitric acid output was calibrated before and/or after each test by using an empty tube in place of a test bed. Acid vapor concentration increased with increasing purge air-flow rate. Nitric acid in bed effluent air or challenge air (empty tube) was measured by continuously drawing part (about 1 L/min) of the effluent air through a bubbler containing 200 mL of water. A pH probe immersed in the bubbler allowed continuous pH measurements with a meter that sent the values to a computer for data acquisition at 1-min intervals. For some tests, we humidified test air by passing it through a chamber containing water. Relative humidity (RH) and temperature (T) were monitored using a dew-point hygrometer upstream of the mixing point.

We put the pH measurements taken at 1-min intervals into a spreadsheet and converted them to acid concentrations. The average slope of concentration vs. time over a selected time interval was obtained by linear regression. It was then converted to an average acid vapor concentration using the bubbler water volume and local atmospheric conditions. The time interval selected for the results reported here was the first 60 minutes. We consider this the most important time interval for the usual application of starting with a freshly opened cartridge. Measurements were actually continued for hours or even days. However, apparent acid breakthroughs (or ammonia

desorptions) dropped off after the first hour and only increased much later. Average apparent breakthrough fraction over the first 60 min was calculated by taking the ratio of average nitric acid concentration in the effluent and the challenge concentration measured before or after the test.

Figure 1 shows a logarithmic plot of measured average breakthrough fractions vs. amounts of GMC-H carbon (the highest weight corresponds to a full-size bed). The most important observation from these tests is that all full-bed equivalent (3.765 g average) measurements at dry and humid conditions showed nitric acid breakthrough fractions less than 0.01 (1%). For the dry (< 25% RH) condition tests with both full and partial bed size equivalents, there were no apparent effects of nitric acid challenge concentration (31-342 ppm), relative humidity (7-25%), or airflow rates (1.95-2.79 L/min). Tests in the 54-60% RH range for 1/4-bed equivalents gave breakthrough fractions in the same range as those obtained at lower relative humidities.

At relative humidities higher than 60% RH, negative apparent breakthrough concentrations and fractions were obtained. These reflect the observation that the sampler water actually decreased in acidity. This will be discussed below. Tests with GME-H carbon full-bed equivalent (5.5 g) tests at dry (< 25% RH) conditions all showed apparent nitric acid breakthrough fractions of 0.0025 (0.25%) or less. The apparent nitric acid breakthrough vapor concentrations increased with challenge vapor concentration. The most interesting observation

in the GME-H tests is that for some blank (no acid challenge) tests and some acid challenge tests at all humidities (19–90% RH), the acidity of the sampler waters decreased. The apparent nitric acid breakthrough concentrations were more negative at higher relative humidities with the GME-H carbon.

The decreases in sampler water acidity mentioned above were attributed to ammonia or some organic amine desorbing from the respirator cartridge carbons. Common practice is to use ammonia salts to enhance the carbon reactivity. After discussions with MSA and Calgon, we concluded that it must be ammonia desorbing from the carbons. This conclusion was confirmed by a mass spectrometric study of the effluent from GME-H carbon. Clear signals at mass peaks 15, 16, and 17 that correspond to the fractionation pattern of ammonia were observed. We saw no other significant mass peaks corresponding to other compounds. Therefore, the negative apparent acid breakthroughs can be taken to be concentrations of ammonia desorbing from the carbons at the test conditions. Figure 2 shows that the ammonia desorption from GME-H becomes most pronounced at relative humidities above 70%. The highest ammonia concentration measured in the first 60 min was 5.5 ppm at 86% RH. Although the GMC-H data are less extensive, it suggests a similar conclusion, with a maximum of 1.7 ppm observed at 73% RH.

These maximums are both well below the ammonia TLV of 25 ppm, but even low releases may be of concern to users sensitive to ammonia. There may also be a right-to-know issue for users. Fortunately for users of these cartridges at Los Alamos, the ambient relative humidity is usually low. Because GMC-H carbon (at least the batch studied) releases less ammonia, GMC-H cartridges might be preferred over GME-H cartridges.

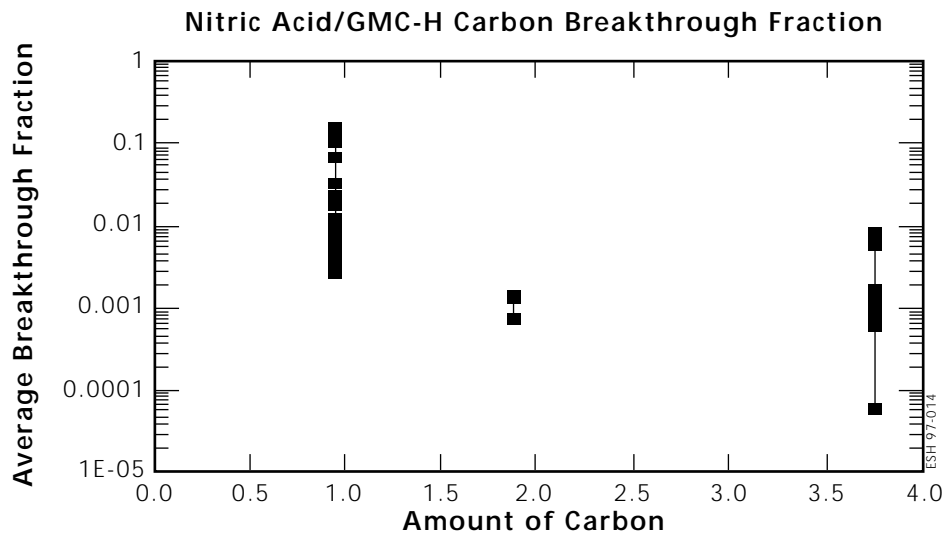


Figure 1. The effect of amount of carbon in a test bed on observed nitric acid breakthrough fractions

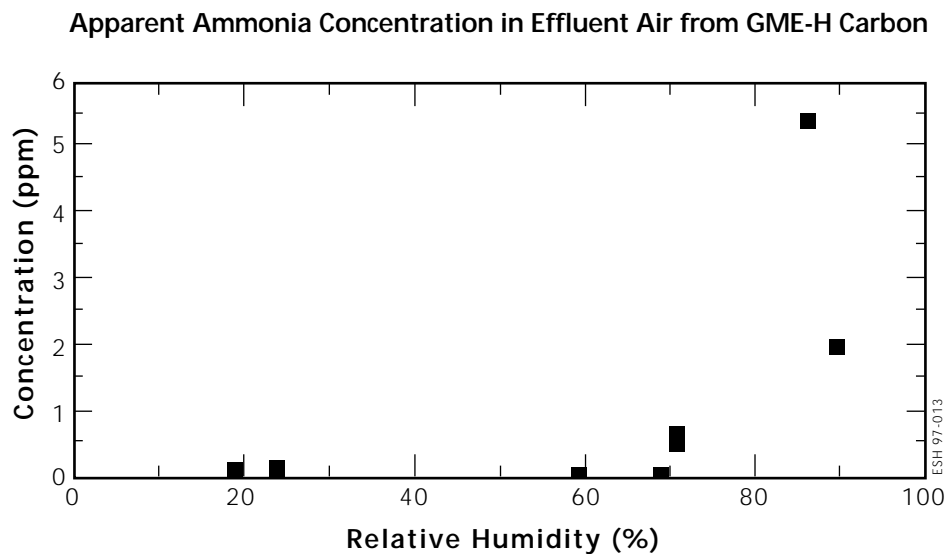


Figure 2. The effect of relative humidity on the release of ammonia from the GME-H carbon

The major conclusion of this study is that both cartridges are very effective in removing nitric acid vapors (>99% removal) from air for at least an hour even at

- low and high humidities,
- high nitric acid vapor concentrations, and
- air flow rates corresponding to breathing at moderately heavy work (50 L/min).

Deliverables

The following are project deliverables:

- Final progress report, October 1996.
- Abstract submitted for presentation at the 1997 American Industrial Hygiene Conference and Exposition, October 1997 (acceptance pending).
- Article for publication in the American Industrial Hygiene Association Journal.

Seasonal Movements, Activity Patterns, and Radionuclide Concentrations of Rocky Mountain Elk (*Cervus elaphus nelsoni*) and Mule Deer (*Odocoileus hemionus*) Inhabiting the Pajarito Plateau

Principal Investigators: P.R. Fresquez, J. R. Biggs, K. D. Bennett, Ecology Group (ESH-20)

Funding: FY96, \$68K

Introduction

From one- to two-thousand elk inhabit Bandelier National Monument and Los Alamos National Laboratory lands. Many of them use Laboratory technical areas known to contain environmental contaminants; consequently, elk may constitute a pathway for transport of radionuclides to man. The objectives of this study are

- Determine seasonal and daily activity patterns of elk on the Pajarito Plateau,
- Evaluate global position system (GPS) test collar data in various plant communities and terrain,
- Apply spatial and temporal analysis of data to evaluate behavioral patterns of elk,
- Compare radionuclide content in elk and deer from the Laboratory with radionuclide content in elk and deer from background locations,
- Estimate committed effective dose equivalent (CEDE) and risk of excess cancer fatalities to people who consume meat from elk and deer that use Laboratory lands,
- Evaluate information about wildlife diseases,
- Develop habitat use models for use in the National Environmental Protection Act (NEPA) process,
- Develop elk habitat use models for management strategies, and
- Identify locales of concern so that management recommendations can be developed to aid local agency officials in minimizing vehicle accidents involving these animals.

Progress and Results

From spring 1995 to spring 1996, we investigated seasonal movement patterns of four elk (three cows and one bull) and one deer, using traditional very high frequency (VHF) radiotracking methods. In 1996, we captured an additional six elk and fitted them with GPS collars. Tritium and disease analyses were conducted for all eleven animals.

Animals fitted with VHF units were tracked for 12-14 months. The deer remained within three miles of its original capture location (n = 39 positions) throughout the study period. The

bull elk remained on the Pajarito Plateau in winter and spring then migrated to Valle Grande during late spring and summer (n = 49 positions). Within six weeks of collaring, one of the three cows died, apparently following calving. The surviving elk cows remained on the east slope of the Jemez Mountains and the Pajarito Plateau during winter and early spring then moved to Valle Grande during calving and the summer months (n = 93 positions). Based on limited VHF radiotelemetry data, we conclude that some herds in the southern portion of the Laboratory migrate and calve along the eastern portion of Valle Grande (see figure 1).

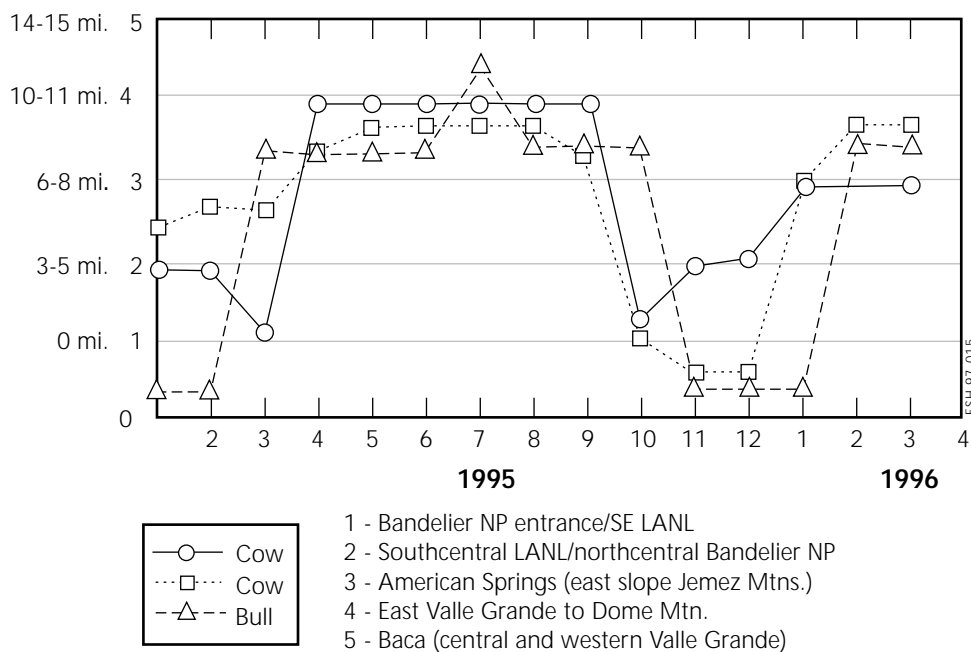


Figure 1. Location of VHF radiocollared elk 1995-96



An elk cow fitted with a GPS collar is released back into the wild.

Of the animals observed, four of the six elk captured in 1996 had moderate to high titers for vesicular stomatitis and one elk had a moderate titer for toxoplasmosis. One cow elk sampled near Pajarito Road and one male deer sampled at TA-49 exhibited concentrations of tritium (2.2 and 1.1 pCi mL⁻¹, respectively) above the upper limit background of 0.9 pCi mL⁻¹.

In 1996, we initiated a study of Rocky Mountain elk using global positioning system (GPS) radio collars to

- Test a new wildlife telemetry system;
- Apply spatial and temporal analysis of data to evaluate activity patterns and resource use of elk; and
- Develop habitat use models to aid in development of long-term management strategies.

In the spring of 1996, we collared six elk (five cows, one bull) with GPS radio collars programmed to locate positions every 23 hours. Between April and December 1996, we collected >200 positions with an approximately 70% reception success rate. We have interfaced GPS-located positions of elk and detailed vegetation maps with the geographical information system (GIS) to provide seasonal habitat use within mountainous regions of northcentral New Mexico. Approximately 65% of elk use on the east slope of the Jemez Mountains takes place within areas of shrub/grass mixtures and piñon/juniper woodlands. The least amount (5%) of use takes place within mixed conifer forests.

We are currently evaluating habitat use in the vicinity of water sources, as well as proximity of locational positions to water sources. We find that greater than 75% of GPS locational positions are located within one mile of surface water sources on the east slope of the Jemez Mountains. Less than 10% of the positions occur greater than two miles from these water sources.

To develop predictive models for application in developing management strategies for this species, we are in the process of determining habitat use by elk, the influence of topographical features on elk movements, and specific movement patterns of elk. We believe the use of GPS collars for elk studies in northcentral New Mexico to be a superior method to that of using VHF radio collars.

As part of this study, we attempted to assess the accuracy of GPS (nondifferentially corrected) positions under various canopies and terrain conditions with the use of a GPS test collar.

With one exception, the length of duty cycle, the test collar was equivalent to collars deployed on six elk. The test collar was activated every 20 minutes to obtain a position location and continuously uplinked to Argos satellites to transfer position data files. We used a Telonics, Incorporated uplink receiver to intercept the transmission and view the results of the collar in real time. We placed the collar on a stand equivalent to the neck height of an adult elk and placed the stand within ponderosa pine, piñon pine/juniper, and open/closed vegetation types. We also collected data on mesa tops and canyon bottoms within these vegetation types. The collar was kept at each location for one hour (usually obtaining three positions). In addition, we used a hand-held GPS to obtain a position of the test collar at the same time and location. The hand-held unit was differentially corrected. Previous tests of the hand-held unit indicated that the accuracy was within two meters of an actual position.

To determine locational error of the test collar within the different treatments, comparisons were made between the test collar and the hand-held GPS following correction. GPS collar-located positions were found to be within 425 ft of the true location (95% CI). There were no statistically significant differences ($\dagger = 0.05$) in locational errors between ponderosa pine and piñon-juniper vegetation types ($p = 0.9672$), open and closed canopies ($p = 0.7950$), or canyons and mesa tops ($p = 0.8459$).

Deliverables

We will prepare and submit three final reports to the TDEA review committee:

- An assessment of elk use on Laboratory property through the use of spatial and temporal analysis of locational point data currently being collected and, if possible, some management recommendations pertaining to human/elk interface problems;
- A model developed with the use of the GIS that will predict movement patterns and resource use on Laboratory property with recommendations for its application to Laboratory project planning and the NEPA review process; and
- An evaluation of radionuclide concentrations in elk, trends, calculation of CEDEs, and the risk of excess cancer fatalities based on the harvest and analysis of elk collected since 1992 and the collared elk.

Publications and Presentations

The publications and presentations listed below have received full or partial funding from the TDEA program. In some instances, a project has been ongoing and TDEA contributed toward supporting progress.

Inkret et al.

Inkret, W. C., and G. Miller, (eds.), "Methods of internal dose assessment," ESH-12-01.01.0, Los Alamos National Laboratory (August 1995).

Miller, G., and W. C. Inkret, "Bayesian maximum posterior probability method for interpreting plutonium urinalysis data," *Radiation Protection Dosimetry*, **63**, 189–196 (1996).

Miller, G., W. C. Inkret, H. F. Martz, "Poisson sum representation of Bayesian posterior means in internal dosimetry," submitted to *Biometrics* (July 1996).

We presented the work described in this report to the 1996 Annual Meeting of the Health Physics Society, Seattle, Washington, and at 1996 Annual Meeting on Bioassay, and Environmental Radiochemistry.

Manuscript in preparation for publication in open literature.

Devine et al.

Casson, W. H., R. T. Devine, and P. A. Staples, "The response of an electronic neutron dosimeter in neutron fields with energies extending up to 600 MeV," *Abstracts for papers presented at the fortieth annual meeting of the Health Physics Society* (1995).

Devine, R. T., S. Walker, P. Staples, R. Mantas, J. Miller, and M. Duran, "Track etch dosimeter response to neutrons up to 300 MeV," *Proceedings of the 1996 International Congress on Radiation Protection*, **4**, 398 (1996).

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Hsu, H.-H and R. T. Devine "Neutron-charged-particle reactions in CR-39 calculated using MCNP and LAHET," *Proceedings of the 1996 Health Physics Society mid-year symposium* (1996).

Miller, A. J., L. S. Walker, P. A. Staples, R. L. Mantas, R. T. Devine, W. H. Casson, M. A. Duran, M. S. Gadd, and V. R. Harris, "High-energy neutron studies at the Los Alamos weapons neutron research facility," *Abstracts for papers presented at the fortieth annual meeting of the Health Physics Society* (1995).

Mundis, R. L., L. S. Walker, P. A. Staples, A. J. Miller, W. H. Casson, M. A. Duran, M. S. Gadd, and V. R. Harris, "Multisphere neutron spectrometry in a high-energy neutron beam," *Abstracts for papers presented at the fortieth annual meeting of the Health Physics Society* (1995).

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Walker, L. S., R. L. Mundis, P. A. Staples, A. J. Miller, W. H. Casson, M. A. Duran, M. S. Gadd, and V. R. Harris, "Response the Albatross neutron dose rate meter to high-energy neutron fields and high-photon dose rates," *Abstracts for papers presented at the fortieth annual meeting of the Health Physics Society* (1995).

Walker, L. S., J. Koster, J. L. Ullmann, P. W. Lisowski, S. A. Wender, and R. L. Mundis; "Comparing the response of an albatross neutron monitor, Bonner spheres and a fission chamber to a known high-energy neutron spectrum in an accelerator beam line," *Abstracts for papers presented at the thirty-ninth annual meeting of the Health Physics Society* (1994).

Walker, L. S., R. L. Mundis, P. A. Staples, A. J. Miller, W. H. Casson, M. A. Duran, and V. R. Harris, "Multisphere neutron spectrometry measurements in a high-energy neutron beam," *Proceedings of the 1996 international congress on radiation protection*, **4**, 569 (1996).

Walker, L. S., C. Pilli, M. A. Duran, R. L. Mundis, A. J. Miller, V. R. Harris, and P. Staples, "Response of a health physics instruments model 2080 Albatross to a high-energy neutron field," *Proceedings of the 1996 Health Physics Society mid-year symposium* (1996).

Mallet et al.

A current works-in-progress presentation of the Laboratory's neutron extremity dosimeter project was made at the annual Bicon-NE User's meeting in Cleveland, Ohio, October 7-11, 1996. Information presented at the meeting and an updated status of the project is published on the ESH-4 web page at esh-4.lanl.gov/mts.

Rodgers et al.

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Hermes et al.

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Macdonald, J., H. Nekimken, R. Hermes, J. Castro, M. Evans, and J. Olivas, "A New Glove for Glovebox Workers," presented at the American Glovebox Society meeting, July 1-3, 1996, San Diego, California (in press as proceedings).

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Fresquez et al.

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